PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A61B 17/36 — A1

(11) International Publication Number: **WO 00/02491**

(43) International Publication Date: 20 January 2000 (20.01.00)

(21) International Application Number: PCT/IL99/00374

(22) International Filing Date: 7 July 1999 (07.07.99)

(30) Priority Data:
60/092,225 9 July 1998 (09.07.98) US

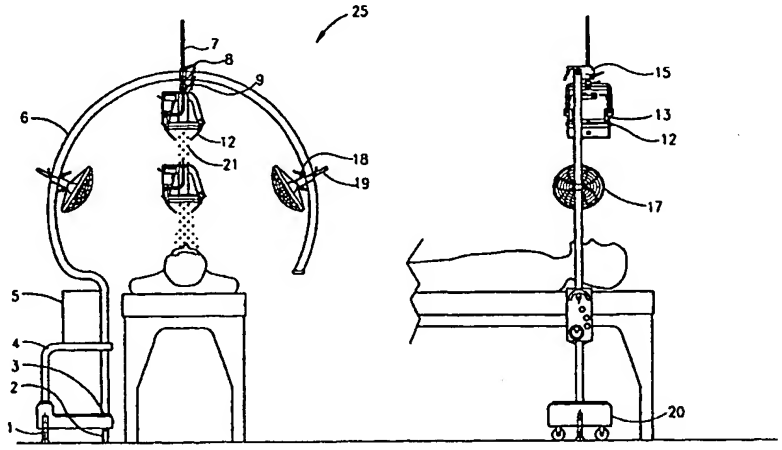
(71)(72) Applicants and Inventors: HARTH, Yoram [IL/IL]; Nordau Street 35, 33124 Haifa (IL). KORMAN, Avner [IL/IL]; Hadar Street 55, 46326 Herzlia (IL).

(74) Agent: EITAN, PEARL, LATZER & COHEN-ZEDEK; Gav Yam Center 2, Shenkar Street 7, 46725 Herzlia (IL).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: APPARATUS AND METHOD FOR EFFICIENT HIGH ENERGY PHOTODYNAMIC THERAPY OF ACNE VULGARIS AND SEBORRHEA



(57) Abstract

This invention is an apparatus, and method for the phototherapy of different skin conditions, particularly acne vulgaris, and seborrhea. The invention consists of a combined treatment with violet/blue light source (13) with a spectral emission in the range of 405 nanometor to 440 nanometer, possible additional spectral bands in the green, the red part of the spectrum, and the topical application of oxygen transporting compounds, and/or a methylene blue solution. The apparatus includes at least one narrow spectral band light source with spectral emitting concentrated in the violet/blue spectral band, and an optical system for controlling spectra, beam parameters of said light source (13), a mechanical fixture (9) for holding said light source (13) at an adjustable distance, the direction related to the skin treated area, an electronic unit (40) to control the duration, the power, and spectral bands of the emitted radiation.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

APPARATUS AND METHOD FOR EFFICIENT HIGH ENERGY PHOTODYNAMIC THERAPY OF ACNE VULGARIS AND SEBORRHEA

FIELD AND BACKGROUND OF THE INVENTION:

The present invention relates to an apparatus and method for the photodynamic therapy treatment of acne vulgaris and seborrhea and, more particularly, to a violet/blue light radiating system that illuminates a collimated narrow bandwidth beam on the treated skin area. The method relates to the combined photodynamic skin treatment including narrow band violet/blue light radiation and topical application of oxidative and/or keratolytic agents.

The enlargement and obstruction of sebaceous glands cause acne vulgaris. Due the accumulation of sebum in the glands, bacteria, mainly propionibacterium acnes (p. acnes), proliferate in the glands. These bacteria cause inflammation and later the formation of pustular lesions and acne cysts, which heal by scarring.

It is known that p. acnes produce porphyrins. It is also known that visible light in the violet/blue (405-410 nanometer range), or less efficiently, red (630-670 nanometer range) are able to induce a photodynamic effect in which the porphyrins in the enlarged sebaceous glands react with oxygen to form peroxides. These peroxides are short-lived toxic compounds that are able to eliminate, or considerably diminish, the number of bacteria in the glands.

Photodynamic therapy (PDT) is based on the optimal interaction of 4 elements; light, photosensitizer, oxygen and skin penetration. Prior patents and publications related to acne phototherapy dealt only with the first two elements of PDT, i.e., and light exposure and sebaceous gland porphyrins. Studies have shown that the photodestruction of p. acnes is increased exponentially in an oxygen rich environment.

Various attempts have been made to treat acne with light; Mendes et al. (US patent 5,549,660) described a method for the light therapy of acne using low intensity red light. Their apparatus was meant to treat acne through it effect on macrophages in the skin. In contrast to the present invention its low light intensity is not sufficient for an efficient photodynamic destruction of p. acnes in the deeper

layers of the skin. High intensity visible light phototherapy for acne was described by Meffert et al., (Dermatol-Monatsschr. 1990; 176(10): 597-603) but they used a light source emitting not only visible light but also UVA comprising up to 15-20% of the total irradiation dose. Sigurdsson et al (Dermatology 1997; 94:256-260). used Philips HPM-10 400W combined with an UVILEX 390- filter (Desag. Germany) that filters most but not all ultraviolet A (UVA) harmful rays. The spectrum of their lamp peaked at 420 nanometer and had 2 other small peak of emission at 405 and 435 nanometer. Their apparatus emitted at 40 cm; 0.5J/cm^2 of UVA, 20 Jcm^2/of violet/blue and 5 J/cm^2 of green light.

There is thus, a widely recognized need for, and it would be highly advantageous, to have a way to practice the enhanced photodynamic therapeutical effect of the combined violet/blue radiation with oxidant or oxygen transporting agents skin treatment by the use of an apparatus and a method to establish these improved treatment healing effects.

Methylene blue is a dye used parentally for treatment of methemoglobinemia in newborns and topically for disinfecting of skin. In vitro and in vivo studies have shown that Methylene blue may be activated by light to induce a photodynamic reaction. Methylene blue was used for the inactivation of herpes virus helicoabacter pillory and for the experimental therapy of skin bladder and esophageal cancers. We claim that our method of photodynamic therapy using may also be enhanced by adding an external photosensitizing agent such as methylene blue in a concentration of 0.1-5%.

SUMMARY OF THE INVENTION

Basic science research has shown in vitro that the viability of p. acnes relates inversely to light intensity and to oxygen levels to which the p. acnes are exposed. Sigurdsson et al achieved with their apparatus 30% reduction of the total severity of acne and particularly 49% reduction of the number of pustules. The rate of success can be drastically improved by adding and penetrating oxygen to the skin daily and / or immediately before skin exposure to high intensity violet/blue light

According to the present invention there is provided an apparatus and a method with improved selectivity and efficiency of acne phototherapy by the use of a specially designed violet/blue and possibly additional spectral line light source, combined with a pre-treatment application on the treated skin area of an oxygen transporting compounds based on the use of one or more of the materials from the group of compounds consisting of perfluorocarbons, oxidative substances, keratolytic substances and external photosensitizer such as methylene blue 0.1-5 %. The apparatus for photodynamic treatment of at least one skin disorder from the group consisting of acne and seborrhea according to the present invention, including: (a) at least one light source with spectral emittance concentrated in at least one specific narrow spectral band, wherein one spectral band is in the range of 405 to 440nm; (b) An optical system for collecting and shaping the emitted light of at least one light source; and (c) An electronic unit to control at least one of the parameters from the group consisting of the duration, power and emitted spectral bands of the light source emittance.

According to further features in the preferred embodiments of the present invention, the apparatus also includes; a mechanical fixture for holding the light source at an adjustable distance and direction related to the skin treated area.

According to further features in the preferred embodiments of the present invention the apparatus also includes; at least one of a group consisting of a liquid filled light guide and a fiber bundle lightguide, as an integral part of the optical system, for collecting and conducting the said light source radiation and illuminating the skin treated area at an adjustable distance, energy density and direction.

According to still further features in the preferred embodiments of the present invention, the apparatus at least one light source is a specially designed Gallium and Lead halides gas mixture discharge lamp with peak emission in the 405-440nm spectral band.

According to still further features in the preferred embodiments of the present invention, the apparatus at least one light source is an Ion Krypton gas laser with a spectral emission in the range 405 to 440nm.

According to still further features in the preferred embodiments of the present invention, the apparatus at least one light source is at least one diode selected from the group consisting of violet/blue laser diodes and light emitting diodes (LED) with narrow spectral band emission in the range 405-440nm.

According to still further features in the preferred embodiments of the present invention, the apparatus light source is any combination of the light sources included in the previously described embodiments.

According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by an elliptical cross-section cylindrical reflector.

According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by a elliptical cross-section cylindrical reflector and further collimated by a set of two orthogonal cylindrical lenses.

According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by a elliptical cross-section cylindrical reflector and is collected at its second focal point by a slit shape input aperture of a slit to circular beam shaping and conducting fiber bundle.

According to still further features in the preferred embodiments of the present invention, the light of the at least one light source is collected by a parabolic cross-section cylindrical reflector.

According to the present invention there is provided a method of treating acne vulgaris and seborrhea with light radiation source having spectral characteristics of at least one of a group of narrow spectral bands consisting of violet/blue (405-440nm), red (630-670) and green (520-550nm) light, combined

with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method including the steps of: (a) application of the at least one compound to the treated skin area; (b) Illuminating the treated skin area with the light radiation source; and (c) at least one additional exposure after a time gap of at least 24 hours.

According to further features in the preferred embodiments of the present invention, there is provided a method of treating acne vulgaris and seborrhea with a high intensity light source, having at least one narrow band violet/blue spectral radiation, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method including the steps of: (a) illuminating the treated skin area with the light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm; (b) concentrating and directing the light on the skin by an optical system and a mechanical fixture; (c) daily and\or pretreatment application of at least one compound selected from the compound group; and (d) 1-5 weekly exposure to violet/blue light for typically 2- 10 weeks, with minimum 24 hours time gap between exposures.

According to still further features in the preferred embodiments of the present invention, there is provided a method of treating acne vulgaris and seborrhea with a high intensity light source, having at least two narrow radiation bands one violet/blue light and one red light, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method including the steps of: (a) illuminating the treated skin area with the light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm and a second wavelength band emittance of 630-670 nanometer range (red); (b) concentrating and directing the light on the skin by an optical system and a mechanical fixture; (c) daily and\or pretreatment application of at least one compound selected from the compound group; and (d) 1-5 weekly exposure to

violet/blue light for typically 2- 10 weeks, with minimum 24 hours time gap between exposures.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the radiation is concentrated and projected on the acne afflicted area with an illumination power in the range of 10mW/cm2 to 500mW/cm2 of violet/blue light radiation.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the concentration of hydrogen peroxide in the applied compound is 1-10% by weight and the concentration of salicylic acid is 1-10% by weight.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the at least one material selected from the group of oxidative and keratolytic compounds is applied either daily or immediately before light exposure.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the oxidative and/or keratolytic compound is within a material selected from the group consisting of a liposome and a positively-charged submicron emulsion.

According to still further features in the preferred embodiments of the present invention there is provided a method wherein the oxidative and/or keratolytic compounds is in a propylene glycol 10-50% base.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the oxidative compound is a oil in water emulsion mixed with molecular oxygen that is sprayed continuously on the skin before or during light exposure.

According to still further features in the preferred embodiments of the present invention, there is provided a method wherein the methylene blue 0.1-5% in distilled water or gel base is applied to the skin before or during light exposure.

The proposed method successfully addresses the shortcomings of the presently known treatment methods and related experimental system configurations. The proposed method provides a new method to enhances in a substantial way the efficiency of the suggested photodynamic therapeutical effect,

by increasing significantly the oxygen pressure in the sebaceous glands through the use of oxygen transporting compounds based on perfluorocarbons and/ or oxidative emulsions. The proposed method also enhances light and compound penetration into the skin using translucent gels and keratolytic agents. It also provide a way to increase the photodestruction of p. acnes by providing high intensity monochromatic light exactly matching the optimal action spectrum of the photosensitizer.

In contrast to the light sources used previously by Meffert and Sigurdsson the present invention apparatus presents a major advance towards the goal of using phototherapy to effectively and safely treat acne and seborrhea. the proposed apparatus emits high intensity non-coherent light in the exact narrow spectral band needed for the activation of the photodynamic reaction flittering the harmful UV light. This narrow and specific wavelength range radiation enables the administration of sufficient intensity of light to the deeper layers of the dermis without excessive heat formation in the epidermis. The required spectral band is emitted by the present invention light source for the photodynamic destruction of p. acnes in the acne sebaceous glands.

In vitro research (Malik Z, Nitzan Y, Harth Y, Korman A. to be submitted for publication) showed that exposure to the proposed apparatus achieves a decrease in propionibacterium acnes from 10^9 to $<10^4$ after two 30, 60 minutes exposures separated by 72 hours of dark incubation. (figure 6)..

In vitro studies show that the destruction of p. acnes may be further enhanced by adding methylene blue 0.5% to the broth prior to irradiation.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic front and side view illustrations of one embodiment of the photodynamic treatment apparatus according to the present invention.

FIGS. 2A and 2B are schematic side view and front view illustrations respectively of the illumination head unit, the same embodiment of the present invention apparatus wherein the illumination unit head structure is based on a violet/blue light source of a gas discharge lamp;

FIGS. 3A and 3B are schematic elevational and bottom views respectively of the light source unit in the apparatus of Fig. 1, in an embodiment wherein the illumination unit structure is based on a circular array of LED's, or laser diodes, emitting a narrow spectral band red light illumination component, the array is integrated on the perimeter of a parabolic cross-section reflector, in the focal point of which is situated a high illumination intensity, narrow spectral band, violet/blue light gas discharge light source;

FIG. 4 is a schematic bottom view illustration of the present invention violet/blue light source, in another preferred embodiment, wherein the illumination unit structure is based on a two dimensional array of LED's, or laser diodes, emitting a preferred narrow spectral band violet/blue light illumination component, the two dimensional array can also include any spatial distribution combination of violet/blue narrow spectral band emitting laser diodes or LED's, together with red light LED's, or laser diodes emitting in the preferred red spectral band;

FIG. 5 illustrates a typical spectral distribution of the light energy emitted by the present invention dedicated violet/blue light source, in the embodiments wherein the light source is a gas discharge lamp;

FIG. 6A - 6C illustrate another set of an additional three preferred embodiments of the illumination head in the apparatus according to the present invention, wherein all these embodiments are based on the application of a single axis elliptical cross-section cylindrical reflector, in the first focal point of which is fitted the illuminating gas discharge lamp arc. The image of the gas discharge light source arc is created in the second focal point of the elliptical reflector and can be

then directly used for object illumination, or collected and further conducted by a fiber optic slit to circular beam shaping bundle, or collected and reshaped by a dedicated set of two orthogonal cylindrical lenses, to optimally conduct and collimate the light energy on the patient's treated skin areas; and

FIG. 7 illustrates the results of the proposed apparatus, laboratory controlled tests on p. acne, showing a decrease in propionibacterium acnes in 4-5 orders of magnitude, after two 30, or 60 minutes exposures separated by 72 hours of dark incubation.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an apparatus, which can be used for photodynamic treatments in phototherapy. Specifically, the present invention can be used for the non-invasive treatment of acne vulgaris and seborrhea, thereby enabling treating various parts of the patient's body with ability to control the illumination power, energy spatial distribution, exposure duration and illumination source emittance spectral bands.

The principles and operation of the apparatus for phototherapy treatment according to the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, Fig 1 is a schematic front and side view illustration of the photodynamic treatment apparatus according to the present invention, which is referred to herein below as system **25**.

System **25** includes a violet/blue light source fixture **13**, which can be moved repositioned and directed to the treated patient specific skin area by adjustment unit **15**. It can also be lifted up or lowered down in order to change the effective radiated energy flux on the treated area, by using pole unit **7** and handle **8**. The apparatus light source is mounted on a mechanical arc shaped fixture **6** for holding and supporting the light source at an adjustable distance and direction related to the patient's treated skin area. The apparatus mechanical fixture **9** allows horizontal, vertical and radial placement and directing of light beam **21** from the light unit **13** to the patient's treated part of the body.

Unit **17** is a schematic presentation of an air blower or a fan that serves to cool and remove access heat from the treated skin area. Units **18** and **19** are mechanisms to adjust required position of unit **17**.

Unit **5** is a control board for the apparatus enabling control of lamp power, illumination duration, air cooling operational parameters and general on/off and mains control functions.

Units **4** and **20** are a structural element and a balancing weight to stabilize the apparatus in a vertical up-right position. Unit **3** is a mechanical axis around which the entire apparatus arc shaped structure **6** can be rotated and refitted in any required horizontal angular position related to the treated patient bed **22**.

Wheel **2** and pole **1** are elements required to move and refit the position of the apparatus according to the operational needs of the system operator.

Light source fixture **13** of consists of a lamp or a laser light source that emits violet/blue light with a peak at 405-420nm. Close to a hundred percent of the light source ultra violet/blue light (UV) is filtered out by an integrated optical system. The required narrow spectral emission band of violet/blue light source is radiated by the present patent dedicated arc lamp due to a special gas mixture within the lamp, or by a gas laser source, or by a violet/blue light emitting semiconductor diode junction. The above light sources in a single source type embodiment, or in a combination of two or three type of light sources, allows optimal violet/blue light radiation with or without additional narrow spectral band lines in the red or green parts of the spectrum. The present invention light source enables the minimization of heat production at the treated target to a max. of 23 degrees Celsius on the epidermis at 30-40 cm. A mechanical shutter **12** in front of the light source **13** may be used to exactly define the treated area.

Figures 2A and 2B are schematic side and front view illustrations of the illumination head unit **13** according to the present invention, referred to herein below as system **28**.

Illumination system **28** includes a filter unit **121** for filtering out the radiated energy spectral part which is out of the preferred specific bandwidth in the violet/blue and/or the red spectrum, as previously described in the above background paragraph of the invention. Unit **111** is a set of four mechanical flaps with a control knob **112** and a pivoting axis **110** that create together an adjustable aperture iris unit to control the size and collimation parameters of system **28** radiated light beam. U shaped arm **114** holds and supports the illumination unit housing **113**. Unit **109** enables rotation of the system **28** around vertical pivot axis **107** and to lock it in the preferred rotational angle. Unit **115** enables changing position by sliding and further fixing in a preferred position system **28** along the apparatus support arc **106**. Unit **115** also enables sliding system **28** up or down and then fixing its position. Unit **122** is an optional mechanical support housing and a lens for focusing and concentrating the system **28** illumination beam on a smaller

area of the treated skin, thus creating a higher light energy flux whenever required for a specific treatment.

Figures 3A and 3B are schematic elevational and bottom view of another preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, referred to herein below as system **30.**

System **30** includes a housing unit **31** and a reflector **32** having preferably a parabolic vertical cross section. The gas discharge lamp **33** is assembled into reflector unit **32** in a way that fixes the center of the lamp illumination arc in the focal point of the reflector. Lamp **33** is a specially designed Gallium and Lead halides gas mixture discharge lamp with peak emission in the 405-430 spectral band.

Unit **34** is a circular array of red emission LED's or red light laser diodes installed around the aperture perimeter of the reflector unit **33.**

Figure 4 is a schematic illustration of another preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, referred to herein below as system **40.**

System **40** includes a housing unit **42** and a two-dimensional array of LED's, or laser diodes **41**, emitting a narrow spectral band violet/blue light illumination component. These semiconductor solid state light sources can be GaN or ZnSe components. The two-dimensional array can also include narrow spectral band red light LED's, or laser diodes, emitting in the preferred red spectral band. Unit **43** is a mechanical structure for attaching system **40** to the apparatus of figure 1.

Figure 5 illustrates a typical spectral distribution of the light energy emitted by the present invention dedicated violet/blue gas discharge lamp based light source, before further spectral optical filtration is done, in the embodiments wherein the light source is a gas discharge lamp.

Figure 6A. is a schematic cross section illustration of one of a set of three possible preferred embodiments of the present invention lighting head unit **13** of the apparatus described in figure 1, the first possible embodiment is referred to herein below as system **50.** Light source head embodiment of system **50** consists of a housing **51** that supports an arc lamp, or a line beam shape laser light source

52 that emits violet/blue light with a peak at 405-420nm. The light source is fixed in the first focal point 54 of an elliptical cross section shape reflector 53. The energy emitted out of the preferred spectral band reflected by the elliptical shaped reflector and is imaged as a line source at its second focal point 55. From the secondary focal point the beam is diverging at a small angle and creates an oval shaped illumination area 81 of typical size 20X10 cm. at a convenient treatment distance of 40 cm. from the lamp housing exit aperture. The non violet spectral part of the light source emission is rejected and filtered out by filter unit 56 and the lamp housing is sealed by tempered glass window 57 possibly coated with a heat mirror layer for the protection of the patient against heat and explosion. The required narrow spectral emission band of violet/blue light source is radiated by the present invention dedicated arc lamp due to a special gas mixture within the lamp, or by a violet/blue light emitting semiconductor diode junction array. The above light sources in a single source type embodiment, or in a combination of two or three type of different spectral emission bands light sources alternative embodiment, allows optimal violet/blue light radiation with, or without additional narrow spectral band lines in the red or green parts of the spectrum.

Figure 6B. is a schematic cross section illustration of a second possible preferred embodiment of the present invention lighting head unit 13 of the apparatus described in figure 1, the second possible embodiment is referred to herein below as system 60. Light source head embodiment of system 60 consists of a housing 61 that supports an arc lamp, or a line beam shape laser light source 62 that emits violet/blue light with a peak at 405-420nm. The light source is fixed in the first focal point 64 of an elliptical cross section shape reflector 63. The energy emitted out of the preferred spectral band reflected by the elliptical shaped reflector and is imaged as a line source at its second focal point 65. In the secondary focal point the beam is entering a slit shape fiber bundle aperture, matching the size and shape of the imaged light line at this point. 68. At the exit circular aperture 67 of this fiber bundle the emerging light is diverging at a typical 40 degrees angle and creates a circular shaped illumination area while its size and consequently the illumination power density can be controlled by changing the distance from the exit fiber end 67 to the patient treated skin area. The non violet spectral part of the

light source emission is rejected and filtered out by filter unit **66** and the lamp housing is sealed by a cover window **69.** The above light sources in a single source type embodiment, or in a combination of two or three type of different spectral emission bands light sources alternative embodiment, allows optimal violet/blue light radiation with, or without additional narrow spectral band lines in the red or green parts of the spectrum.

Figure 6C. is a schematic cross section illustration of a third possible preferred embodiment of the present invention lighting head unit **13** of the apparatus described in figure 1, the third possible embodiment is referred to herein below as system **70.** Light source head embodiment of system **70** consists of a housing **71** that supports an arc lamp, or a line beam shape laser light source **72** that emits violet/blue light with a peak at 405-420nm. The light source is fixed in the first focal point **74** of an elliptical cross section shape reflector **73.** The energy emitted out of the preferred spectral band reflected by the elliptical shaped reflector and is imaged as a line source at its second focal point **75.** After passing through in the secondary focal point **75** the beam is entering a set of two cylindrical lenses **76** and **77,** which are orthogonal oriented in respect of their linear axis. At the exit of this lens system aperture **78** a close to a circular light illumination area is created of typical size 20X20 cm. at a convenient treatment distance of 40 cm. from the lamp housing exit aperture. The non violet spectral part of the light source emission is rejected and filtered out by filter unit **79** and the lamp housing is sealed by a cover window **80.** The above light sources in a single source type embodiment, or in a combination of two or three type of different spectral emission bands light sources alternative embodiment, allows optimal violet/blue light radiation with, or without additional narrow spectral band lines in the red or green parts of the spectrum.

FIG. 7 illustrates the results of the proposed apparatus laboratory controlled tests on p. acne showing a decrease in propionibacterium acnes 10^9 to $<10^4$ after two 30 and 60 minutes exposures separated by 72 hours of dark incubation.

The method according to the present invention improves the present art treatment methods in a major way by adding oxygen transporting compounds

based on perfluorocarbons and/or oxidative and /or keratolytic agent, daily and or immediately pretreatment. The proposed oxygen transporting agents i.e., perfluorocarbons lipophilic emulsion, release nascent oxygen directly into the sebaceous glands achieving a 76% O_2 environment as compared to the atmospheric 20%. The proposed oxidative agents i.e., emulsion or gel of H_2O_2 1-10%, release by contact with the enzyme cathalase present in the skin nascent oxygen. The specific formulations of the emulsion or gel prevent the upward release of the oxygen and cause a short temporary inward pressure of up to 15 Atm. of O_2, penetrating to the sebaceous situated in the deeper layers of the skin.

The oxygenation of the skin during the phototherapy process raises the efficiency of the desired photodestruction of p. acnes and thus decreases of acne lesion number and severity. Added keratolytic agent (i.e. 1-5% salicylic acid) to the applied formulation will enhance diffusion of O_2 into the sebaceous glands. Cooling of the applied emulsion or gel minimizes the heat in the epidermis thus allowing a further increase of the light intensity in the sebaceous glands.

It is to be understood that the invention is not limited in its applications to the details of construction or drawings. The invention is capable of other embodiments, or of being practiced or carried out in various ways. Also, it is to be understood that the phraseology and terminology employed above is for the purpose of description and should not be regarded as limiting. While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

CLAIMS

1. An apparatus for photodynamic treatment of at least one skin disorder from the group consisting of acne and seborrhea, comprising:

(a) at least one light source with spectral emittance concentrated in at least one specific narrow spectral band, wherein one spectral band is in the range of 405 to 440nm;

(b) An optical system for collecting and shaping the emitted light of said at least one light source; and

(c) An electronic unit to control at least one of the parameters from the group consisting of the duration, power and emitted spectral bands of said light source emittance.

2. The apparatus of claim 1. further comprising:

a mechanical fixture for holding said light source at an adjustable distance and direction related to the skin treated area.

3. The apparatus of claim 1. further comprising:

at least one of a group consisting of a liquid filled light guide and a fiber bundle lightguide, as an integral part of said optical system, for collecting and conducting said light source radiation and illuminating the skin treated area at an adjustable distance, energy density and direction.

4. The apparatus of claim 1, wherein said at least one light source is a specially designed Gallium and Lead halides gas mixture discharge lamp with peak emission in the 405-440 spectral band.

5. The apparatus of claim 1, wherein said at least one light source is an Ion Krypton gas laser with a spectral emission in the range 405 to 440nm.

6. The apparatus of claim 1, wherein said light source is at least one diode selected from the group consisting of violet/blue laser diodes and light emitting diodes (LED) with narrow spectral band emission in the range 405-440nm.

7. The apparatus of claim 1, wherein said light source is any combination of the light sources included in claims 4, 5 and 6.

8. The apparatus of claim 1, wherein the light of said at least one light source is collected by an elliptical cross-section cylindrical reflector.

9. The apparatus of claim 1, wherein the light of said at least one light source is collected by a parabolic cross-section cylindrical reflector.

10. The apparatus of claim 8, wherein the light of said at least one light source is collected and further collimated by a set of two orthogonal cylindrical lenses.

11. The apparatus of claim 8, wherein the light of said at least one light source is collected at its second focal point by a slit shape input aperture of a slit to circular beam shaping and conducting fiber bundle.

12. A method of treating acne vulgaris and seborrhea with light radiation source having spectral characteristics of at least one of a group of narrow spectral bands consisting of violet/blue (405-440nm), red (630-670) and green (520-550nm) light, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method comprising the steps of:

application of said at least one compound to the treated skin area;

Illuminating the treated skin area with said light radiation source; and

at least one additional exposure after a time gap of at least 24 hours.

13. A method of treating acne vulgaris and seborrhea with a high intensity light source, having at least one narrow band violet/blue spectral radiation, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method comprising the steps of:

illuminating the treated skin area with said light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm;

concentrating and directing the light on the skin by an optical system and a mechanical fixture;

daily and\or pretreatment application of at least one compound selected from said compound group; and

1-5 weekly exposure to violet/blue light for typically 2- 10 weeks, with minimum 24 hour's time gap between exposures.

14. A method of treating acne vulgaris and seborrhea with a high intensity light source, having at least two narrow radiation bands one violet/blue light and one red light, combined with the application of at least one compound selected from a group consisting of topical oxygen transporting perfluoroocarbon and oxidative agent and keratolytic agent and methylene blue solution. The method comprising the steps of:

illuminating the treated skin area with said light source having a narrow bandwidth emittance within the wavelength band of 405-440nm filtered for ultraviolet/blue under 400nm and a second wavelength band emittance of 630-670 nanometer range (red);

concentrating and directing the light on the skin by an optical system and a mechanical fixture;

daily and\or pretreatment application of at least one compound selected from said compound group; and

1-5 weekly exposure to violet/blue light for typically 2- 10 weeks, with minimum 24 hours time gap between exposures.

15. A method of treating acne vulgaris and seborrhea with in accordance to claim 12, wherein the radiation is concentrated and projected on the acne afflicted area with an illumination power in the range of 10mW/cm2 to 500mW/cm2 of violet/blue light radiation.

16. The method according to claim 12; wherein the concentration of hydrogen peroxide in the applied compound is 1-10% by weight and the concentration of salicylic acid is 1-10% by weight.

17. The method according to claim 12, wherein at least one material selected from the group of oxidative and keratolytic compounds is applied daily.

18. The method according to claim 12, wherein the material selected from the group of oxidative and keratolytic compounds is applied immediately before light exposure.

19. The method according to claim 12, wherein the material selected from the group consisting of oxidative and keratolytic compounds is cooled.

20. The method according to claim 12, wherein the material selected from the group consisting of oxidative and keratolytic compounds is in an aqueous gel.

21. The method according to claim 12, wherein the material selected from the group consisting of oxidative and keratolytic compounds is in oil in water emulsion.

22. The method according to claim 12, wherein the oxidative and/or keratolytic compound is within a material selected from the group consisting of a liposome and a positively charged submicron emulsion.

23. The method according to claim 12, wherein the oxidative and/or keratolytic compounds is in a Propylene glycol 10-50% base.

24. The method according to claim 12, wherein the oxidative compound is a oil in water emulsion mixed with molecular oxygen that is sprayed continuously on the skin before or during light exposure.

25. The method according to claim 12, wherein methylene blue 0.1-5% in distilled water or gel bases is applied to the skin before or during light exposure.

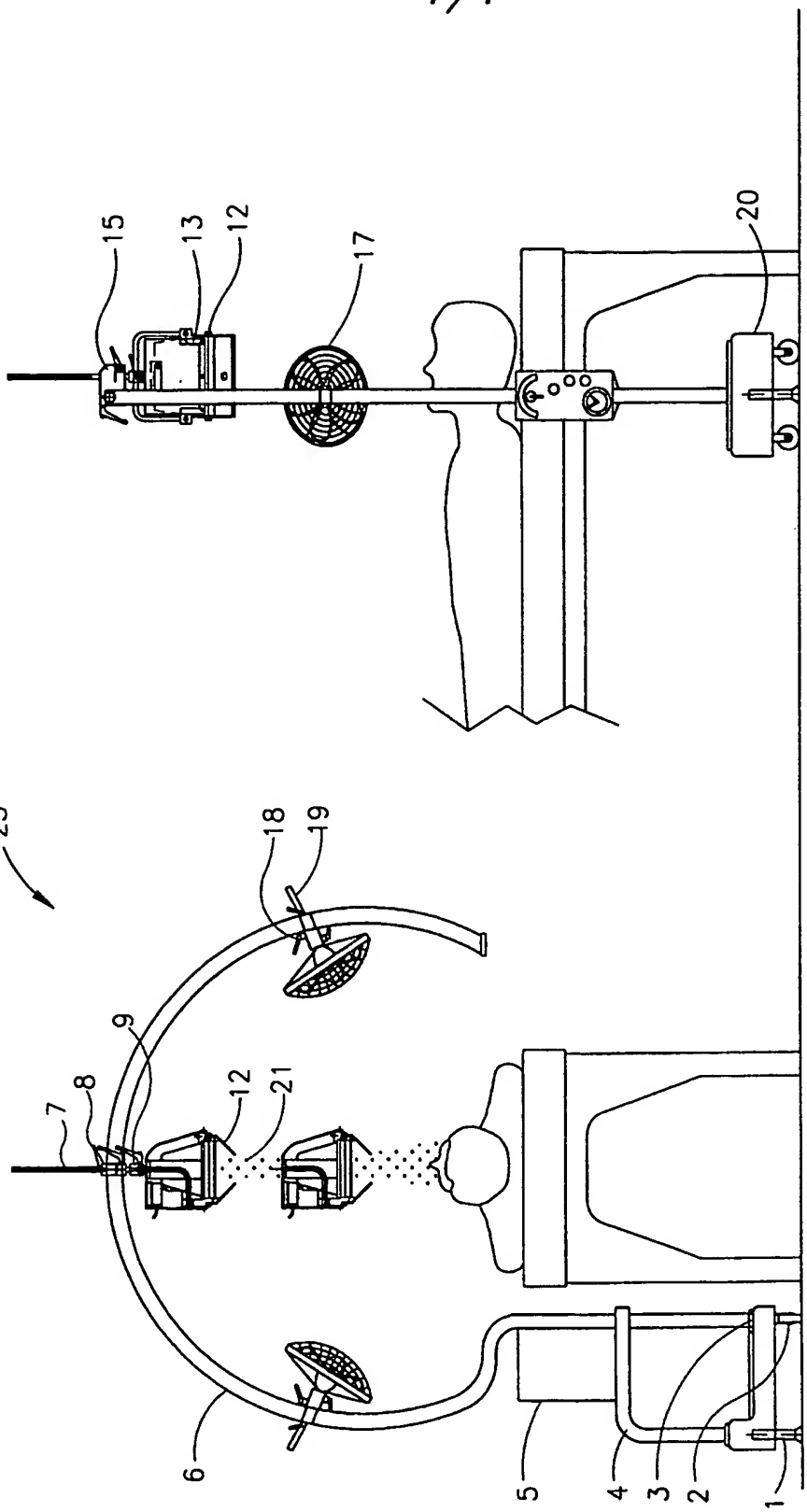


FIG.1

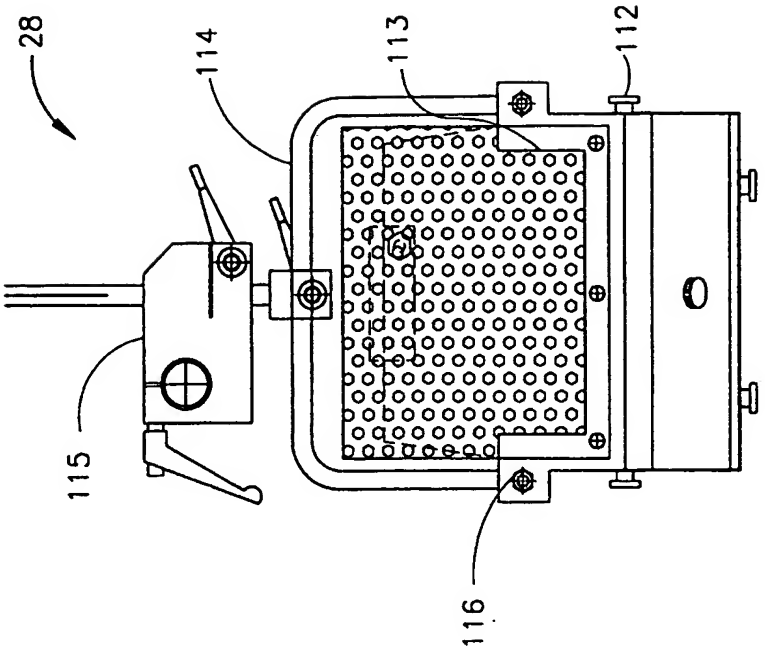


FIG.2B

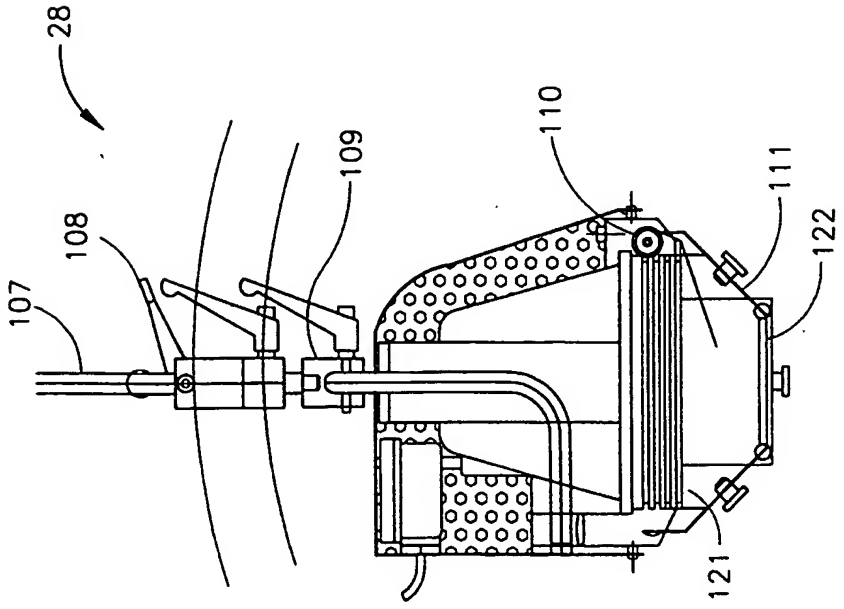


FIG.2A

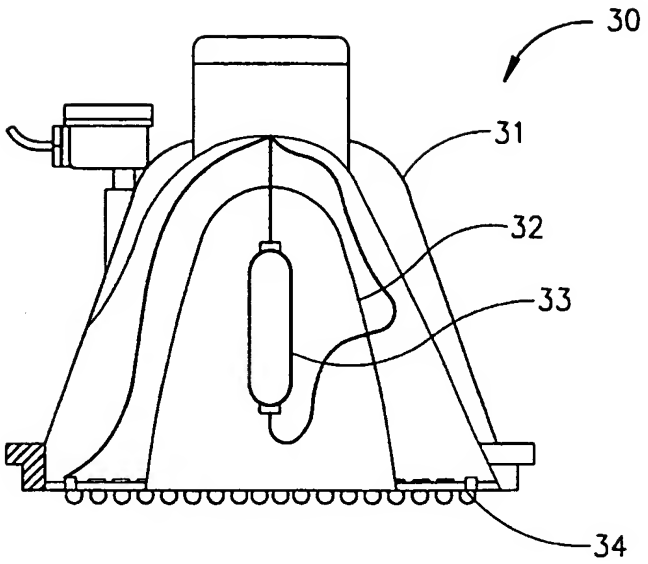


FIG.3A

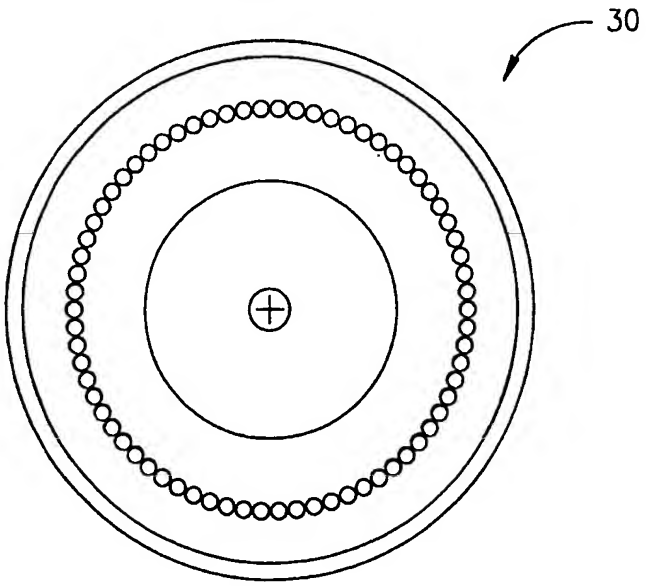


FIG.3B

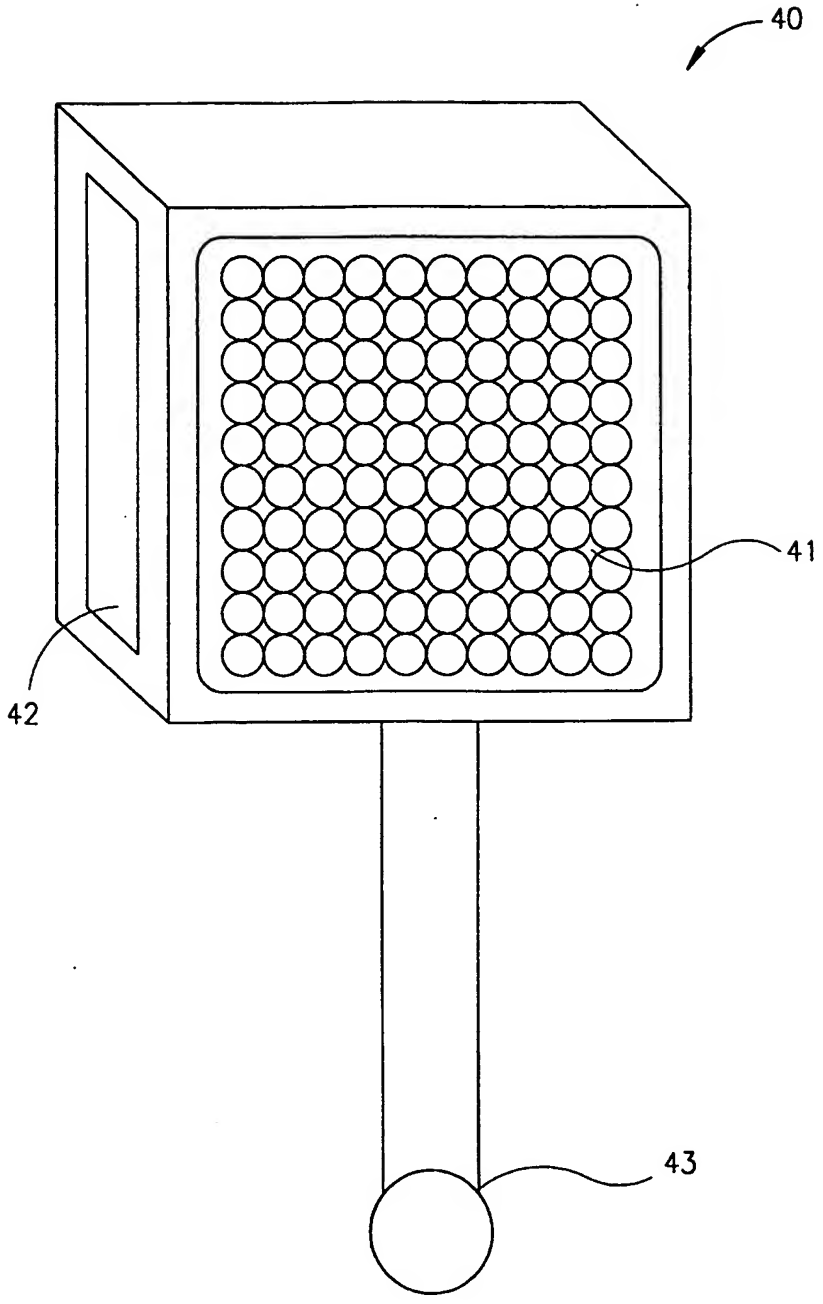


FIG.4

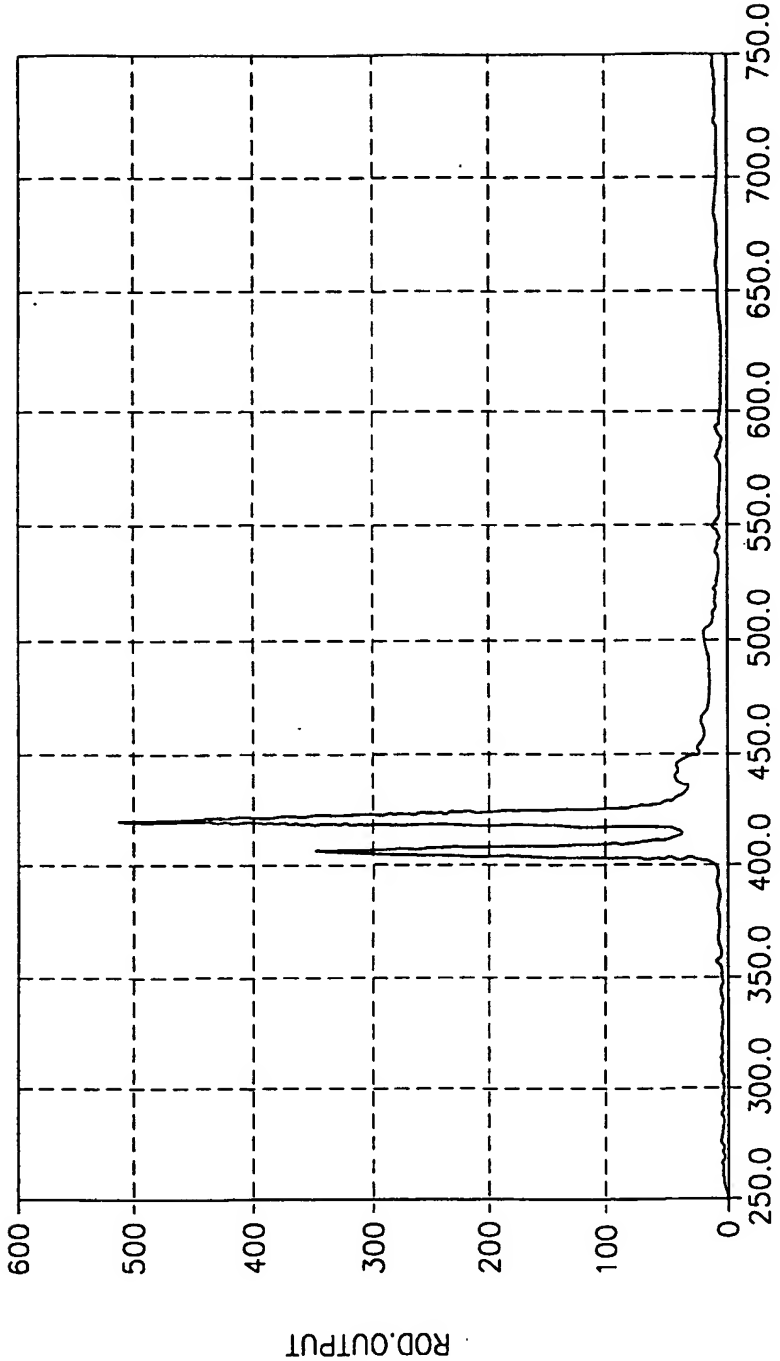

ROD.OUTPUT
600
500
400
300
200
100
0
250.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
700.0
750.0
WAVELENGTH,NM

FIG.5

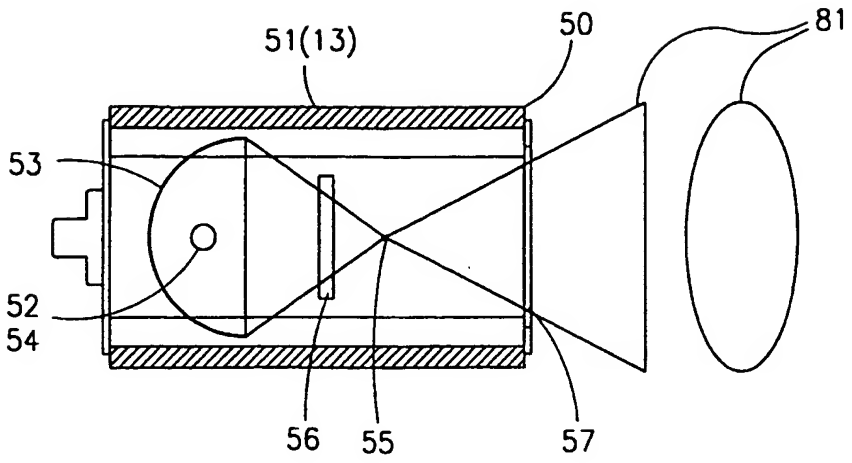


FIG.6A

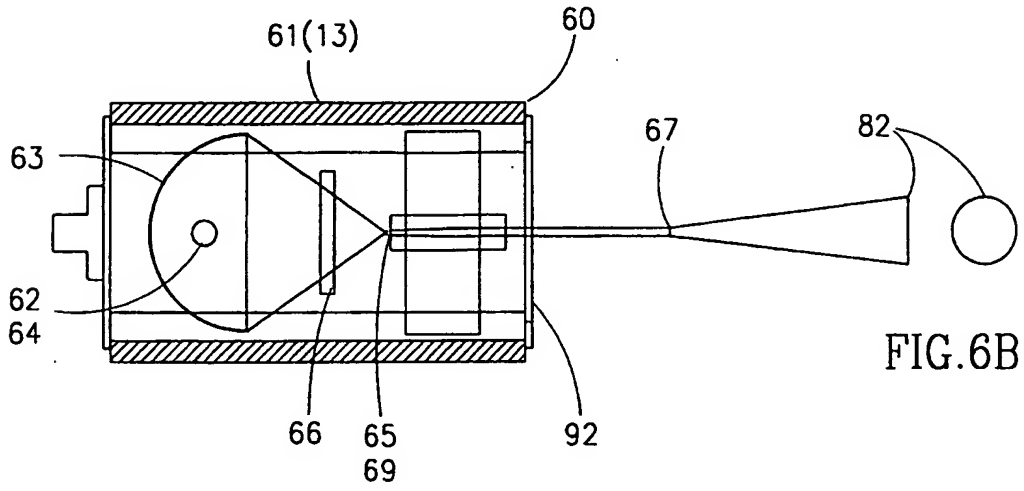


FIG.6B

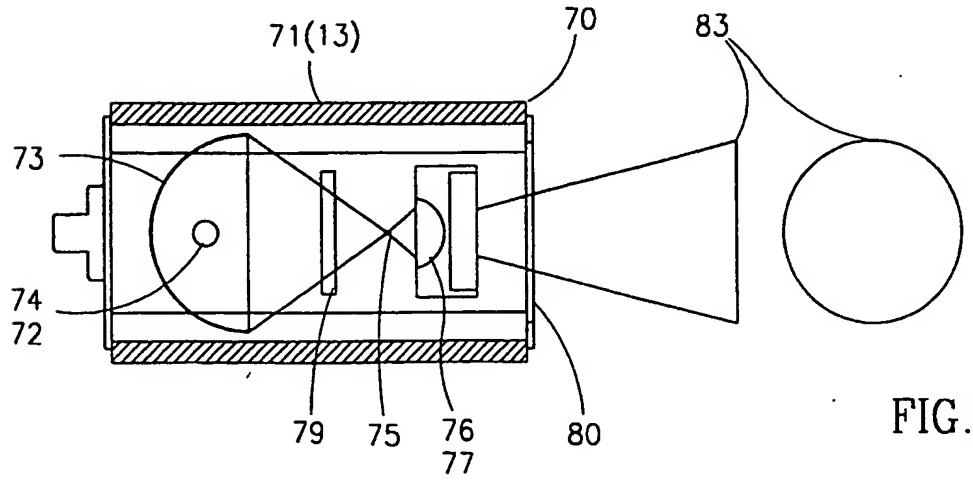


FIG.6C

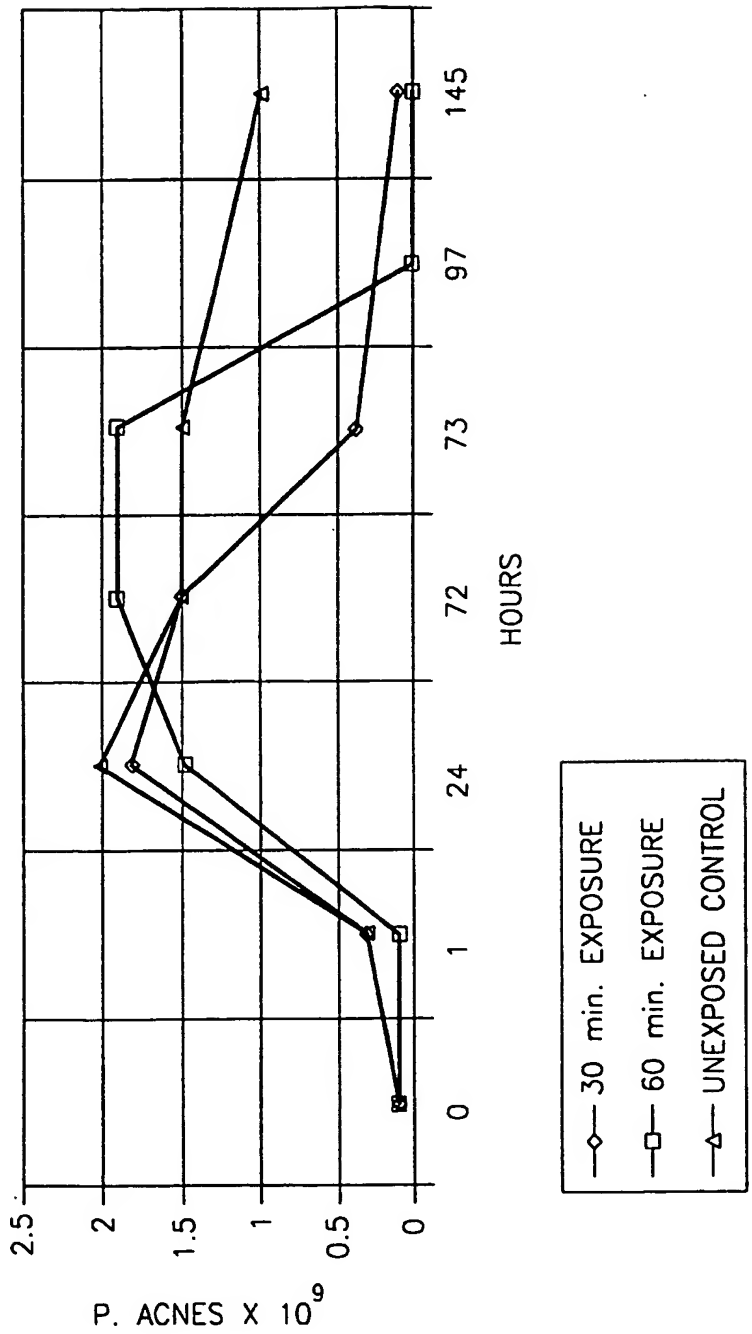

2.5
2
1.5
1
0.5
0
P. ACNES X 10^9
0
1
24
72
73
97
145
HOURS
30 min. EXPOSURE
60 min. EXPOSURE
UNEXPOSED CONTROL

FIG.7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00374

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61B 17/36
US CL :606/009; 607/88

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 606/1, 3, 9, 16, 17, 19; 607/88-90

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US 5,817,089 A (TANKOVICH et al.) 06 October 1998, see entire document.	1-25
A	US 5,707,403 A (GROVE et al.) 17 January 1998, see entire document.	1-25
A, P	US 5,879,376 A (MILLER) 09 March 1999, see entire document.	1-25

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 25 OCTOBER 1999	Date of mailing of the international search report 14 DEC 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer SONYA HARRIS-OGUGUA Telephone No. (703) 308-2216

Form PCT/ISA/210 (second sheet)(July 1992)*